The "afterthought" phenomenon in stress: impacts of retrospective appraisal on stress responses

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Abstract: **Background:** While psychosocial stressors trigger neuroendocrine responses and affect task performance, many studies overlook the dynamic nature of the stress appraisal process. **Goal:** This study aims to explore whether subjective appraisals at various time points can interpret individual stress responses, both behaviorally and physiologically, using controlled laboratory conditions. **Methods**: A total of 137 effective participants were recruited to induce individual stress states using the Trier Social stress Test (TSST). Subjective appraisals were measured both before (anticipatory appraisal) and after the stressor (retrospective appraisal). Concurrently, participants' cortisol responses and task performances were documented. **Results:** Findings indicate that anticipatory appraisal doesn't significantly impact task performance, whereas retrospective appraisal markedly affects performance of the corresponding tasks. Regarding cortisol levels, multivariate regression analysis revealed that only the retrospective appraisal of the speech task accounted for the observed variance in cortisol response under stress. **Discussion:** The data suggests that retrospective appraisals are more indicative of behavioral and physiological responses to psychosocial stressors than anticipatory appraisals. These findings lend empirical support to refining the biopsychosocial model and underscore the utility of retrospective appraisal in capturing individual stress response variations.

Keywords: stress, retrospective appraisal, behavioral performance, cortisol response

Introduction

All organisms inherently strive to maintain a state of homeodynamic balance, also known as the dynamic homeostasis. This balance is vital when faced with disruptions from various factors in both their internal and external environments (Agorastos & Chrousos, 2022; Chrousos, 1995; Nicolaides et al., 2014). In order to sustain the homeostasis, organisms have evolved intricate systems to respond to both physical and psychological stressors (Chrousos, 2009; von Dawans et al., 2021). Compare with the autonomic nervous system (ANS) which address to the stressor rapidly, the hypothalamus–pituitary–adrenocortical (HPA) axis offers a slower response to stress, mainly through the secretion of glucocorticoids, such as cortisol in humans (Chrousos, 2009; Lin et al., 2021). A wealth of research indicates that maladaptive stress responses can be linked to an array of mental and physical disorders, including anxiety, depression, and various cardiovascular diseases (Cohen et al., 2007). Therefore, understanding the human stress response is of primary importance.

It is crucial to recognize that stress is not merely a generic blend of physiological and psychological reactions triggered by stimuli. Indeed, even when confronted with an identical stressor, different individuals can exhibit varying responses (Kirschbaum et al., 1999; Sapolsky, 2015). To elucidate the nuances of these stress responses, Lazarus and Folkman (1984) introduced the Transactional Theory of Stress. This theory posits an essential appraisal process that mediates between the stressor and the subsequent response. It is the individual's assessment of demands and resources that ultimately determines their reaction to the stressor. More precisely, this cognitive appraisal process can be broken down into two stages: the primary appraisal, which assesses the potential significance or implications of the stressor, and the secondary appraisal, which steers individuals towards identifying the most effective coping strategies (Bityutskaya & Korneev, n.d.; Carpenter, 2016; Folkman et al., 1986; Lazarus & Folkman, 1984).

Subjective appraisal plays a pivotal role in modulating the stress response, its influence is evident not just in behavioral outcomes but also in physiological reactions. A substantial body of research has delved into the repercussions of appraisal on task performance. Findings reveal that, whether in competitive scenarios like athletic competitions (Calmeiro et al., 2014) or in socially evaluative situations such as public speaking (Lyons & Schneider, 2005), individuals who perceive their resources to exceed task demands consistently outperform those who assess their resources as insufficient. Furthermore, the contents of subjective appraisal also shapes neuroendocrine responses, as exemplified by variations in cortisol secretion in response to stressors (Olff et al., 2005; Pulopulos et al., 2020; Quested et al., 2011).

When discussing appraisal, it is commonplace to measure the outcome of appraisal at a singular time point. However, it is essential to understand that the appraisal process is dynamic, suggesting that individuals might recalibrate their appraisal outcomes throughout the stress

experience (Eschleman et al., 2012). Specifically, initial primary and secondary appraisal outcomes can shape the coping strategies individuals employed to deal with the stressor. As these strategies manifest in behavioral and physiological responses, they alter the individual's environment, which, in turn, influences subsequent appraisals. This dynamic nature complicates pinpointing a specific moment when appraisal accurately represents the entirety of the process and its relationship with stress responses.

Categorizing appraisals based on their timing can help: one of a kind is anticipatory appraisal, which precedes the stressor, and retrospective appraisal, which follows it. Anticipatory appraisal is rooted in an individual's internal schema, heavily intertwined with cognitive processes. This schema frames how individuals interpret their environment, formulating expectations of imminent stressors and thus priming them to anticipate specific outcomes (Riegler, 2001). An individual's foresight regarding a stressor and their self-assessed coping ability can guide the allocation of cognitive resources during preparatory phases, allowing for strategic adjustment in coping mechanisms (De Raedt & Hooley, 2016). Conversely, retrospective appraisal, conducted post-stressor experience, encapsulates an individual's reflection on past events (Pitts et al., 2018), often aligning with personal recollections of the stressor (Lomeli, 2015). However, memories can be reshaped by emotional input, making emotions a pivotal determinant in retrospective appraisal (Schmidt, 2004). A study by Folkman and Lazarus (1985) segmented appraisals into three phases surrounding a midterm examination: anticipation (pre-exam), waiting (post-exam, pre-results), and outcome (post-exam, post-results). Their findings indicated that anticipatory appraisals were problem-focused, leveraging cognitive components to evaluate upcoming stressors and informing preparatory actions. In contrast, during the waiting and outcome stages, the focus shifted to evaluating the significance of the past stressor and interpreting results. With outcomes fixed and unchangeable, problem-focused coping reduced, supplanted by emotion-focused coping strategies. In essence, while anticipatory appraisal invokes an active, cognition-driven state, retrospective appraisal is more passive and emotion-oriented.

Currently, there's a limited body of literature examining the distinctions between anticipatory and retrospective appraisal. One notable study in this realm was undertaken by Gaab and his colleagues (2005). They enlisted 81 healthy young male participants and gauged both anticipatory and retrospective appraisal before and after administering the Trier Social Stress Test (TSST). Their findings underscored the significant role of anticipatory appraisal in determining cortisol response to stress. However, the study's exclusive focus on males and lack of task-specific appraisal for the TSST might have introduced ambiguities in the outcomes, potentially leading to misleading findings such as the attenuated importance of retrospective appraisal.

Building on these findings, our study aims to delineate the influence of subjective appraisal at different junctures on individuals' stress responses, both physiologically and behaviorally. We induced a stress state using the widely-recognized psychosocial stress task, the TSST, and captured subjective appraisal both pre (anticipatory) and post (retrospective) stressor. Our primary objective was to ascertain if retrospective appraisal serves as a credible predictor of observed

behavioral and physiological stress responses, as per our hypothesis. By addressing these inquiries, we aim to furnish more robust evidence, enriching our understanding and thereby contributing to a comprehensive biopsychosocial framework.

Method

Participants

According to existing related research(Lin et al., 2022; Wang et al., 2021), the following exclusion criteria were applied during participants recruitment to minimize the impact of potential confounding factors: (1) taking any drugs within 2 weeks prior to the experiment; (2) a history of neuroendocrine disease or long-term use of related medications; (3) presence of severe chronic physical or mental diseases; (4) significantly disrupted circadian rhymes or chronic engagement in night shift; (5) heavy drinking or smoking within 2 weeks of participating in the experiment; (6) having oral wounds or other oral diseases; (7) pregnant females or those taking hormonal contraceptive. Female participants were asked to avoid their menstrual phase on the day of the experiment.

Based on an prior sample size calculation with G*power 3.1, at least 68 participants were needed in a linear multiple regression analysis with $\rho^2 = 0.3$(Lin et al., 2021), predictors = 6, power($1-\beta$) = 0.95, α = 0.05. To obtain a valid dataset, a total of 137 participants were recruited by online screening, all of whom were right-handed and had normal or corrected vision. Seventeen participants were excluded from analysis due to the following reasons: 7 participants with missing data withdrew from experiment; cortisol samples from 4 participants did not meet the quality criteria for analysis; and data recording errors occurred for 6 participants. Ultimately, 120 valid data sets were retained for analysis, including 62 males (51.7%). The average age of participants was 22.40 (SD = 2.50), and the range of age was 17-28 years. The mean BMI of participants was 21.28 ± 2.62. All participants gave their informed consent before participation and received a monetary compensation.

The study was approved by the ethics committee of the Institute of Psychology, Chinese Academy of Sciences.

Materials

Experimental self-report measures

Anticipatory appraisal

In this experiment, the Primary Appraisal Secondary Appraisal (PASA) scale was used to measure individual's anticipatory cognitive appraisal before completing a stressful task. The PASA scale was developed based on the cognitive appraisal theory proposed by Lazarus and Folkman (1984) and further refined by Gaab and his colleagues (2005). The scale assesses two sub-processes of cognitive appraisal, namely primary appraisal (PA) and secondary appraisal (SA).

The scale of PA includes the dimension of 'threat' (e.g., 'I do not feel worried because the situation does not represent any threat for me') and the dimension of 'challenge' (e.g., 'This task challenges me'), while the scale of SA consists of two dimensions: 'self-concept of own abilities' (e.g., 'In this situation, I know what I can do') and 'control expectancy' (e.g., 'It mainly depends on me whether the experts judge me positively'). Each of these dimensions includes four items that measure the outcome of self-reported appraisal, comprising a total of 16 items in the PASA scale. Participants were asked to rate each item on a scale from 1 to 6 based on their current feelings (1 = "Strongly disagree"; 6 = 'Strongly agree').

The results of PASA can be determined by computing the difference between the mean value of SA and the mean value of PA. A higher resultant value signifies a stronger conviction among individuals who believe that their ability is enough to cope with the task demands. The internal consistency of PASA, as represented by Cronbach's α, ranges from 0.63 to 0.83, which indicates reasonable (> 0.60) to good (> 0.80) consistency (Gaab et al., 2005). Base on the data obtained in this study, the Cronbach's α is 0.68-0.78, thereby substantiating the good internal consistency of the PASA assessment.

Retrospective appraisal

Drawing from relevant literature, the Visual Analogue Scales (VAS) were used to measure the levels of threat, challenge, self-concept and perceived control following the completion of a stressful task (Crichton, 2001; Gaab et al., 2005; Kirschbaum et al., 1999). Since participants were subjected to two distinct tasks designed to induce stress, the VAS was used twice to assess the effects of each task (i.e., Speech task & Calculation task) separately. The dimensions of 'threat' (e.g., 'The stress level I felt during the speech/calculation task.') and 'challenge' (e.g., 'The level of challenge of former speech/calculation task.') constitute the primary appraisal (PA), while the secondary appraisal (SA) is comprised of 'self-concept' (e.g., 'The ability I displayed in former speech/calculation task.') and 'perceived control' (e.g., 'The level of control of the results of speech/calculation task I perceived').Participants were instructed to rate each item on a scale from 0 to 10 (0 = completely inconsistent, 10 = completely consistent).

Similarly, the index of VAS can be derived from the scale results (overall appraisal = SA - PA). The Cronbach's α for each sub-dimension of VAS were calculated based on the data obtained in this study. The results showed that the scale exhibits good internal consistency, with α values ranging from 0.828-0.924.

Experimental biochemical measures

Saliva samples were collected with Salivette collection tube (Sarstedt, Rommelsdorf, Germany). During the sample collection process, the participants were instructed to place the sterile cotton strip beneath the base of their tongue for 1-2 minutes until the tampon was saturated with saliva. Following collection and labeling, saliva samples were stored at -22℃ for subsequent biochemical analysis. Cortisol concentrations in saliva samples were measured utilizing the Roche Cortisol Test Kit II (Cortisol II, Roche Diagnostics, Numbrecht, Germany). The lowest sensitivity for cortisol is 1.5nmol/L, with an allowable inter-assay variation of less than 12.7% and an intra-assay variation of less than 7.1%. The area under the response curve was calculated with respect of increase (AUCi), serving as an indicator of the integrated cortisol response. The index represents the physiological state of participants during stressful task.

Psychosocial stress test

The Trier Social Stress Test (TSST) paradigm, developed by Kirschbaum et al. (1993), has been extensively utilized in the laboratory studies to investigate acute stress (Birkett, 2011; Kudielka et al., 2007; Reschke-Hernández et al., 2017). Meta-analysis have found that TSST can excite significant response in the hypothalamus-pituitary-adrenal (HPA) axis, inducing stable and relatively lasting cortisol responses (Allen et al., 2014; Dickerson & Kemeny, 2002, 2004; Kudielka et al., 2004, 2007). Existing studies also prove that the TSST paradigm possesses high validity among Chinese participants (Lin et al, 2021; Lei, 2021). Consequently, TSST was chosen as the task to induce the stress state of participants. TSST comprises three phases: preparation (5min), public speech task (5min) and mental calculation task (5min), for a total of 15 minutes. During the preparation phase, the experimenter introduced the task requirements to participants in the preparation room. Participants were instructed to imagine being accused for shoplifting by a security guard in a supermarket, and they had to defend for themselves in front of several supermarket managers. These managers would evaluate participants' speech performance, and the entire process will be videoed for subsequent experts to review. Participants may use pen and paper for note-taking during preparation but must deliver their speech without any prompts.

In the speech phase, participants were led to the speech room and give a 5-min speech in front of three unfamiliar experimenters ('managers'). Throughout this process, experimenters provided no task-related feedback, and must score the participants' performance based on 'eye contact', 'voice quality', 'speech fluency', 'speech comfort'. The 'integral stress level' scores served as an indicator of participants' speech performance.

Subsequently, the experimenter instructed participants to complete a 5-min mental calculation task, requiring participants to continuingly subtract 13 from 1022 and verbally report each calculation result. If participants make any error, they must stop and restart the task. The minimum results participants achieve was recorded, and the difference between baseline and TSST performance was used as an indicator for the calculation task.

Procedure

When recruiting participants, the baseline of calculation task was measured with computer, and there was no timer or other stressors like the formal experiment did. The demographic information was also collected during the recruitment.

To minimize the effect of circadian rhythm on cortisol, all participants were arranged to complete the experiment between 2:00 PM and 5:00 PM in the afternoon (Kirschbaum et al., 1993; Reschke-Hernández et al., 2017; Wang et al., 2021). To prevent diluting of cortisol levels in saliva, participants were not permitted to eat or drink once the experiment commenced. The experiment procedure is shown in **Fig 1**.
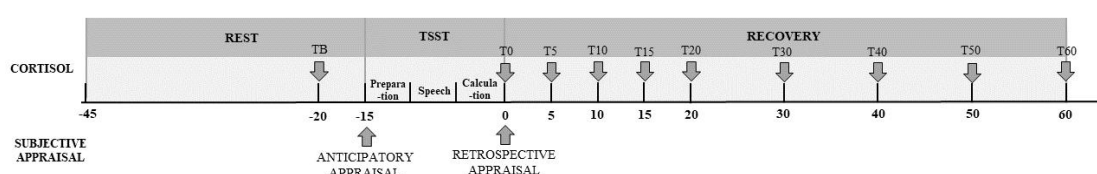
Figure 1 General experimental procedure. Cortisol levels were collected at baseline, immediately after the TSST, 5 min, 10 min, 15 min, 20 min, 30 min, 40 min, 50 min, and 60 min post- TSST. Subjective appraisals were collected before and after TSST with scales.

Participants initially entered an isolated laboratory and completed a 30-min acclimation period, during which they were provided with magazines to read. Simultaneously, they completed the informed consent forms. Following the acclimation period, baseline salivary cortisol samples (TB) were collected. Participants then entered the preparation room to prepare for the speech task after confirming their understanding of the task requirements. They also completed the PASA questionnaire to provide anticipatory appraisals for the upcoming speech task.

Upon the conclusion of the preparation period, participants were led into the speech room and completed the TSST. Immediately after the TSST, the experimenter guided the participants back to the preparation room (less than a 30-second walk) to collect salivary cortisol measurements and complete VAS at Time 0-minute (T0). Two separate VAS assessments were conducted for retrospective appraisal of speech task and calculation tasks. Participants continued to rest in the preparation room, and salivary cortisol measurements were obtained at 5, 10, 15, 20, 30, 40, 50, and 60 min (T5, T10, T15, T20, T30, T40, T50, and T60) (Kirschbaum et al., 1993; Lin et al., 2022; Wang et al., 2021).

Data analysis

Initially, a one-way repeated ANOVA of the salivary cortisol data was performed to verify whether the stress paradigm can effectively induce participants' stress response (Lin et al., 2021;

Vijayan et al., 2010). Subsequently, the relationship between subjective appraisal and behavioral and physiological response were examined through a series of multivariate linear regression analysis: (1) the task performance of speech and calculation task as outcome variables; (2) the cortisol response (AUCi) as the outcome variable. The independent variables included appraisal results for different tasks at various time points. Gender and age were incorporated as control variables in the performance models, while age, BMI and the menstrual cycle for female were also controlled in the cortisol response model.

The statistical analysis was conducted with SPSS 25.0. All reported p-value were two-tailed with the level of significance at 0.05.

Results

Verification of the validity of the paradigm

A one-way repeated measures ANOVA was conducted using cortisol levels as within-subjects variable. The results showed a significant the main effect of within-subjects factor ($F(9, 1071) = 121.39$, $p < 0.001$, partial $\eta^2 = 0.51$), and the variation trend of cortisol can be observed in **Fig 2**. Post-hoc analysis showed that the cortisol concentrations significantly increased from baseline (5.09 ± 2.65 nmol/L) to 0 min after the TSST (7.89 ± 4.27 nmol/L), 5 min after TSST (10.44 ± 5.73 nmol/L) and 10 min after TSST (12.32 ± 7.05 nmol/L), with each time point showing a significantly higher cortisol level than the previous one. The cortisol concentration reached its peak value 10 minutes after the TSST task and subsequently began to decline. Further analysis revealed no significant difference between baseline and the end of measurement period ($t(119) = 0.25$, $p = 0.80$).
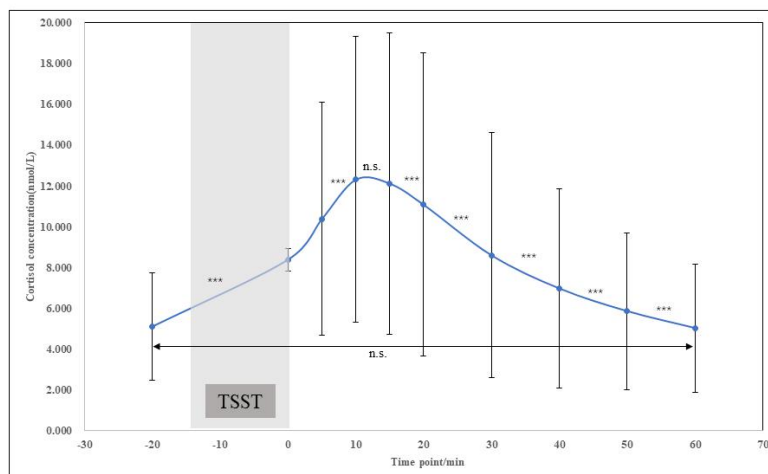
Figure 2. The means of cortisol levels from raw data are shown during the experiment. There is a robust increase before T10, and it reaches the peak value. After T15, the concentration of cortisol decreases slowly. The curve reflects the reactivity and recovery of cortisol.

Regression analysis

To explore the relationship between subjective appraisal in different time points and participants' stress response, multivariate linear regression analysis is conducted to examine potential associations between variables.

Subjective appraisal and task performance

We conducted two multivariate regression models to explore the relationships between

subjective appraisals and stressful task performance. The multivariate regression models were controlled for age and gender, with the results displayed in **Table.1**. Anticipatory appraisals did not significantly predict performance on either the speech task or the calculation task (*ps.* > 0.05). Contrarily, retrospective appraisals of the speech task significantly accounted for the variance in speech performance ($\beta = 0.301$, $t = 2.893$, $p = 0.005$) while retrospective appraisals of calculation significantly accounted for the variance in calculation performance ($\beta = 0.413$, $t = 4.438$, $p < 0.001$).

Table 1 Multivariate regression on indicators of speech and calculation performance.

	speech performance					calculation performance				
	β	t	p	VIF	R^2	β	t	p	VIF	R^2
gender	0.128	1.417	0.159	1.076		-0.062	-0.705	0.483	1.076	
age	-0.034	-0.376	0.708	1.09		-0.065	-0.738	0.462	1.09	
anticipatory appraisal	0.131	1.345	0.181	1.245	0.134	-0.058	-0.611	0.542	1.245	0.178
retrospective appraisal of speech	**0.301**	2.893	0.005	1.428		-0.118	-1.165	0.247	1.428	
retrospective appraisal of calculation	-0.003	-0.029	0.977	1.198		**0.413**	4.438	0.000	1.198	

Subjective appraisal and physiological response

According to existing studies, we included age, BMI and the menstrual cycle of female participants as the control variables in the multivariant regression model. The results showed that retrospective appraisals of the speech task significantly accounted for the variance in the integrated cortisol response regarding increase ($\beta = -0.217$, $t = -1.988$, $p = 0.049$).

Table 2 Multivariate regression on indicators of AUCi.

	AUCi				
	β	t	p	VIF	R^2
age	-0.003	-0.027	0.978	1.129	
BMI	-0.036	-0.365	0.716	1.164	
menstrual cycle	-0.092	-0.932	0.353	1.151	
anticipatory appraisal	0.004	0.042	0.967	1.251	0.052
retrospective appraisal of speech	**-0.217**	-1.988	0.049	1.421	
retrospective appraisal of calculation	0.005	0.05	0.96	1.212	

Discussion

In our study, we recruited 137 healthy college students to explore whether subjective appraisals at various time points serve as valid indicators of stress responses, both behaviorally and physiologically. The results demonstrated that the TSST, as implemented in our study, effectively elicited an acute stress response in participants, as indicated by cortisol concentration levels. The retrospective appraisal of the speech task was a significant contributor to the reactive performance of the same task. Similarly, the retrospective appraisal of the calculation task substantially explained the variance in performance for that task. Conversely, anticipatory appraisals did not correlate with the performance of either the speech or calculation tasks. Moreover, regression analyses revealed that the retrospective appraisal of the speech task significantly accounted for the differences observed in cortisol stress responses. These results support our hypothesis that retrospective appraisal is a primary determinant of an individual's stress response.

The primary finding of our study is that retrospective appraisal, rather than anticipatory appraisal, holds a central correlation with stress response. To understand this result, it's essential to delineate the distinction between these concepts. Appraisal results do not remain constant during the stress process; individuals may alter their subjective appraisals post-stress experience. Consequently, it's imperative to investigate anticipatory and retrospective appraisals distinctly. From an emotional standpoint, the experimental results from Folkman and Lazarus (1985) highlight that the emotion component is more prominent in retrospective appraisal than in anticipatory appraisal. This emotional component significantly correlates with individuals' responses to external stimuli. Supporting this, Barrett's (1998) dimensional emotion theory posits that the arousal dimension of emotion aligns closely with the concept of action readiness. This suggests that appropriate emotional responses prepare individuals more adeptly to adapt to external stimuli, optimizing the attainment of their objectives (Laborde, 2016; Lench et al., 2011). Further focusing on stress, Smith and Lazarus (1990) emphasized the intrinsic link between emotion and stress response, positing that one's emotional state offers profound insights into potential behaviors when confronted with stressors. Beyond theoretical evidence, empirical research by Ashkanasy and colleagues (2003) in workplace settings ascertained that stress-related emotions mediate the influence of workplace stressors on both individual and organizational performance, further underscoring the emotion-stress response.

Given that anticipatory appraisals aim for enhanced allocation of cognitive resources and retrospective appraisals seek to provide superior explanations of current outcomes, it's evident that anticipatory appraisals possess a more substantial cognitive component than do retrospective appraisals. However, during anticipatory appraisal, which demands precise information to bolster cognitive processing, individuals often lack comprehensive details about the stressor and available resources. In contrast, after directly experiencing a stressful task, individuals gain a clearer

understanding, culminating in the biopsychosocial model where subjective appraisals (from a retrospective standpoint) and physiological responses harmonize. Furthermore, while cognition is anticipated to formulate superior strategies against subsequent stressors, many studies, including those by Kusev and his colleagues (2017), assert that behavioral influencers predominantly stem from emotions rather than cognitive evaluations.

Moreover, from a physiological perspective, there is compelling evidence indicating that the processes of retrospective appraisal and HPA (hypothalamic-pituitary-adrenal) axis activation share overlapping anatomical structures. Research across both animal models (Radley et al., 2006) and human studies (Urry et al., 2006) has demonstrated that the prefrontal cortex (PFC) plays a pivotal role in modulating the stress response of the HPA axis (Lopez et al., 2018). Concurrently, the PFC has been recognized as playing a significant role in retrospective appraisal. A meta-analysis by Buhle et al. (2014) indicated that the reappraisal process, which occurs following the onset of a stressor, is associated with the activation of both the dorsolateral prefrontal cortex (DLPFC) and the ventrolateral prefrontal cortex (VLPFC). Importantly, these areas show partial overlap with the brain regions involved in HPA activation. Furthermore, retrospective appraisal can influence the activity of the bilateral amygdala, a critical structure given that the amygdala serves as the intermediary through which the PFC affects the HPA axis (Buhle et al., 2014; Lopez et al., 2018).

Furthermore, our results revealed that only the retrospective appraisal of the speech task accounted for the variance in cortisol levels. Al'Absi et al. (1997) discovered that while both the speech and calculation tasks elicited significant endocrine responses, the speech task led to more pronounced changes in cortisol concentration compared to the calculation task. This observation was corroborated in subsequent studies (Al'Absi et al., 2002). In essence, the speech task emerges as the primary stressor influencing individuals' cortisol responses.

Our findings highlight that only task-specific appraisal outcomes account for the variance in targeted task performance. Broadly speaking, the planning related to actions and the alignment between intended and actual plan implementation hinge largely on individual task-specific appraisals (Niemivirta, 2002). While there's limited research in this domain, an empirical study by Tanaka (2007) identified a substantial impact of task-specific appraisal on individual task performance. Extending this understanding, other studies have posited that self-reported appraisal results tied to specific tasks or challenges (e.g., self-efficacy) are more indicative of individual problem-solving performance than those based on broader domains (Bandura et al., 1999; Pajares & Miller, 1995).

Several limitations of this research warrant mention, and future experiments should address these outstanding questions. Firstly, when constructing the biopsychosocial model, cortisol was the sole physiological index we evaluated. While cortisol is a key marker, numerous physiological indicators can delineate an individual's stress response.(Blascovich et al., 2004; Vine et al., 2013). Subsequent research could incorporate a broader range of indicators to enrich the biopsychosocial

model. Secondly, while the laboratory-based acute stress paradigm (TSST) effectively induces individual stress responses, it diverges from stress scenarios individuals face in real-world operational contexts. To enhance the real-world applicability of our findings, experiments conducted in actual workplace settings would be valuable.

To conclude, our research provides a nuanced understanding of how subjective appraisal at varying timeframes correlates with behavioral and physiological responses in stress contexts. Unlike many studies that assess stress at a singular point in time, our innovative approach captures the dynamic evaluation process of stress both before and after the stress event. By focusing on cortisol as a physiological indicator and delving into the roles of anticipatory and retrospective appraisal, this study illuminates the complexities of stress reactions. Notably, our findings underscore the prominent role of retrospective appraisal in understanding variations in stress responses, challenging some traditional views in the biopsychosocial model. This not only enhances our comprehension of individual stress mechanisms but also reaffirmed the importance of context-specific appraisals in psychological research on stress.

Conflict of Interest:

The authors have no conflict of interest to disclose.

Data availability statement:

The raw data and analysis codes of this research are available from the corresponding author, Dr. Liang Zhang, with reasonable request.

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